WIND ENERGY ACTIVITIES IN AFRICA

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PREFACE

A variety of sources were used in surveying wind and water data for the various countries cited in this report. In some countries masses of data are available, in others very little. However, in most cases it is a question of trying to fit together various pieces of information whose reliability is uncertain.

The wind information presented in the country sections is based on the available information from research reports and meterological services generally written in the respective countries. Often the anemometry equipment used, anemometer exposure, method of data-taking and compilation, or length of record are not known. Thus it is not known how representative such surface data is. It may not indicate a wind potential that exists, or it may show energy that doesn't exist. In some cases different data sets are inconsistent. Thus all such information should be viewed as preliminary. All countries need further wind energy evaluation. Still, the past efforts are presented here to show readers the extent of the work done. This is only a beginning, and is essential to a full evaluation.

A second body of wind information is presented in the wind energy map (Figure 1). The authors are indebted to Dennis Elliott of Battelle Pacific Northwest Laboratories in Richland, Washington, USA, who kindly provided the map. It is an excerpt from the paper, "World-Wide Wind Resource Assessment."[1] This map is the result of an analysis of surface and upper air data by a team of professionals from a variety of disciplines. It is viewed as an important step in the evaluation of wind energy in Africa. It is interesting to note that in some cases the map shows significant differences from earlier surface data evaluations described in the text. More work still remains to be done to improve the wind data base for Africa. Any attempt to use wind energy in Africa should be accompanied by a site specific evaluation of the winds as well as technology options and the economics of wind energy use.

VITA plans to update this survey of wind activities in Africa periodically and welcomes corrections and updates to be included in the next revision. If you would like to be placed on a mailing list to receive future updates of this paper, please contact Alan Wyatt or Sam Baldwin at VITA directly.

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[1] "World-Wide Wind Resource Assessment", N.J. Cherry, D.L. Elliott, and C.I. Aspliden. Proceedings of the Fifth Biennial Wind Energy Conference and Workshop. Washington, D.C. Available from the National Technical Information Service, Springfield, Virginia 22161.

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WIND, A NEW AND AN OLD SOURCE OF ENERGY

The energy situation in Africa is reaching critical levels. Skyrocketing prices for diesel fuel, kerosene, and gasoline put a heavy strain on both individual families and businesses in Africa. The price tag for human, agricultural, and industrial development continues to rise everyday. Drought and overgrazing have greatly reduced the supply of two of the most basic commodities, water and firewood.

In the face of these rising costs and scarcities, many African governments, businesses, and individuals are turning to renewable sources of energy as a possible means to help alleviate a deepening crisis. The utilization of these energy sources can provide a local solution to a difficult energy problem, reduce the work load on an already over-taxed population, and increase the health and living standard of African people.

Wind energy has played a significant role in the development of the Netherlands, Australia, South Africa, Britain, and the United States. Hundreds of thousands of windmills have provided the energy for lifting water for household, irrigation, and livestock use in the past. In the nineteenth century, windmills were a reliable and well-known technology. But with the advent of cheap fossil fuels, the windmill declined. Now as conventional fuel prices rise, the windmill is being viewed with interest. In Africa, wind energy is a possible source of mechanical energy for water lifting and, to a lesser extent, for grain grinding. Wind electric power could also provide electric power for institutions such as schools, clinics, or small businesses.

Wind power in Africa is not new. Many water pumping windmills have been used in the past in a variety of places. Some have worked well but a large number have failed, due mainly to a lack of maintenance and spare parts. Winds are too low in many areas to make a windmill economically viable for water pumping. Even where economic in the long run, windmills have not been an affordable technology for the majority of African farmers and householders due to their large initial capital cost. A number of efforts have been made to initiate small scale production to produce low cost windmills adapted to African conditions, but the results are mixed. Significant production has been ongoing for a number of years in South Africa and Cape Verde. Recent efforts have initiated production in Kenya and Tanzania on a small scale. Much work remains to be done to encourage local production, measure and analyze wind data, and train local people in the construction, installation, and maintenance of wind machines.

This paper provides an overview of wind energy activities in Africa, past and present. First, some general trends in the present situation are identified. Second, suggestions are made as to possible involvements by private enterprise, donor agencies, and African governments in wind power development in the African context. Finally, a brief description is given by country, of wind data, water resources, past and present uses of wind power, and research and development activities. A list of contacts for each country is included as an appendix so that readers may obtain additional information directly if desired.

WINDPOWER IN AFRICA TODAY

As we will see, wind and water resources and data, institutional capabilities, energy needs, and research and development levels vary widely in the African coutries. Nonetheless, a few tentative generalizations can be made on the basis of this preliminary survey.

Wind Resources

Wind energy resources in Africa have not been carefully measured. Large areas have no wind data measuring systems at all. The most common device that does exist in Africa, the counter cup totalizer, can provide only a rough indication of the wind energy potential as it records the mean speed--which can be difficult to correlate to available energy. Still, a number of areas have been identified as potential regions of good wind power availability, including the Senegal/Mauritania coasts and nearby islands, the northern part of the Sahelian region of West Africa, the Rift Valley/Lakes region of East Africa, the coastal areas of East Africa, and parts of South Africa. Other regions may also have wind potential, but have not been properly surveyed. Much of the interior of the continent has fairly low winds. See figure 1.

Imported Windmills

Over the past fifty years or so a number of attempts have been made to use imported "multiblade" water pumping windmills imported from Australia, the United States and Britain. With the exception of South Africa, there has been no large or widespread program to use windmills. The scattered efforts undertaken have often suffered from breakdowns due to dust and sand, saline water, lack of spare parts infrastructure, and lack of proper maintenance.

The underlying problem in all breakdowns has been the high initial cost of windmills and a general lack of knowledge of their use. Only a small segment of the population, often foreign residents, were aware of the possible uses of wind power. This fact, combined with a climate of only moderate winds and the high cost of wind machines, resulted in only a small demand for windmills. Individual importation of water pumpers was the result and consequently no infrastructure has been developed to provide spare parts, service, or proper training for installation and maintenance. The windmill has remained an expensive foreign object to most Africans. Given a more systematic approach combining local production, training, and maintenance, a far more wide spread and reliable use of wind power could develop.

Local Production of Windmills

The case of South Africa provides an interesting contrast to much of the rest of Africa. South Africa, with its large, relatively well developed industry and agriculture, lack of oil, and reasonable winds, created a market and infrastructure in which windmill production and use could flourish. Many thousands are in use today. It is not surprising then that other countries in Africa now actively pursuing wind energy are generally nations without their own oil resources, but with a growing industrial and agricultural base and moderate winds.

AFRICA - WIND ENERGY RESOURCE

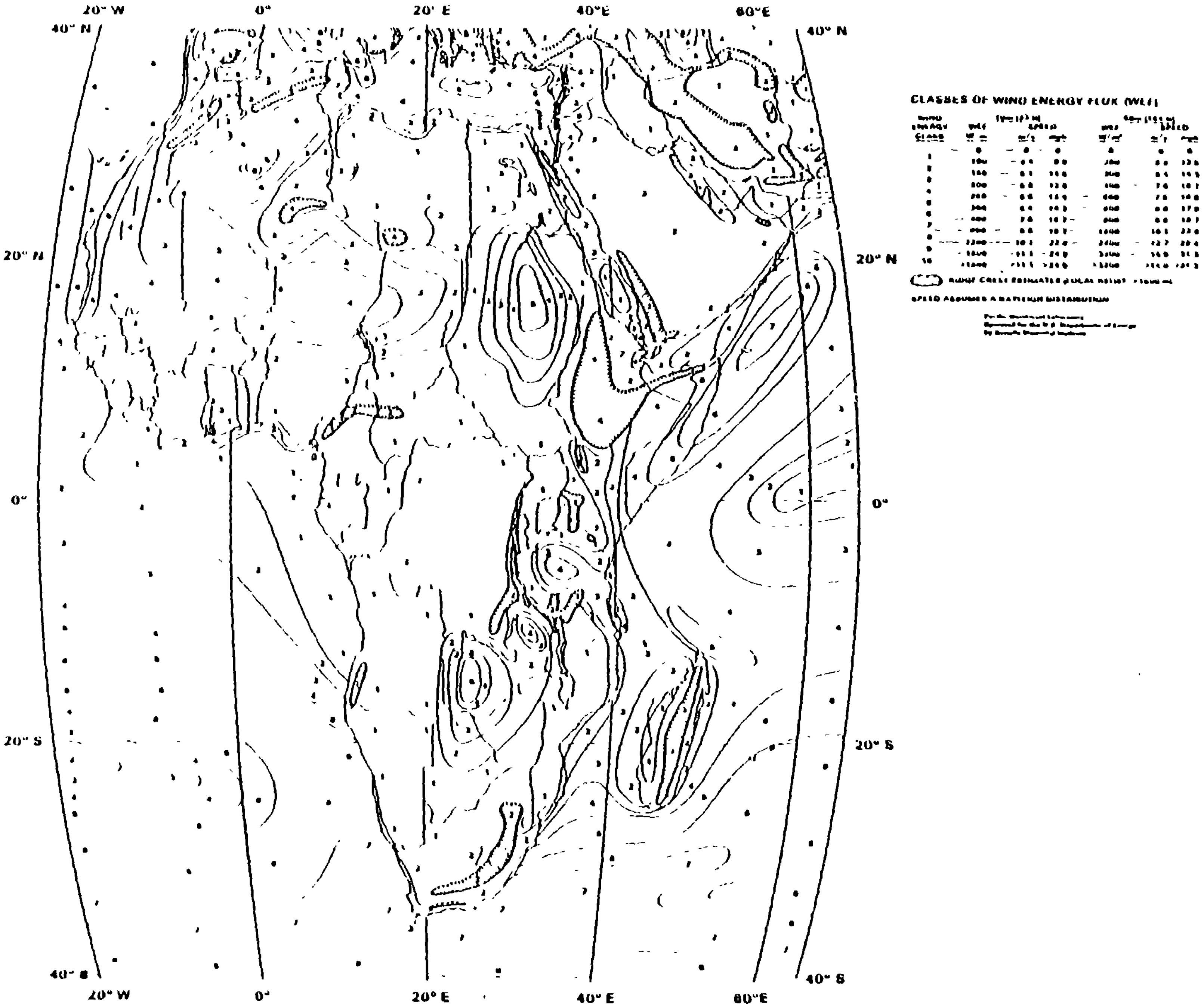

FIGURE 1

Local production is underway on a small scale in a number of countries, including Cape Verde, Tanzania, and Kenya. Their objective is to produce "appropriate" water pumping devices at a significantly lower cost than imported windmills. Technical, marketing, management, and training issues still need to be addressed and will likely take some time to develop adequately. A well coordinated effort combining business and government will be needed.

Economic Feasibility

General statements about economic feasibility of wind power are hard to make. Wind data, equipment cc , ~aintenance requirements, and water requirements, as well as costs of purchase, operation and maintenance of alternative equipment (mainly diesel) all need to be considered and will vary according to location. One interesting model for comparing water pumping windmills to diesel engine sets allows a "break-even" price for diesel fuel to be established (Gingold, 1979). If diesel prices are above their break-even point, then the windmill may make sense. For example, the 5m Harries wind pumper from Kenya costs about $5,500 including tower and installation. In a 3.3 m/s average wind it will pump about 18,700 m^3/year. When compared to a diesel engine, break-even price of US $1.50 per gallon is found.

Diesel fuel in Kenya reached that level two years ago and is even higher now. However, in a 2.2 m/s wind the break-even price comes out to about $3.75/gallon. While just one example, it is illustrative of the present situation. Reducing the cost and increasing the efficiency of windmills still require much work.

Use

Use of wind power for water pumping has attracted the majority of interest in Africa. Little attention has been given to the use of windmills for grain grinding, which is also an important energy consumer in Africa. The feasibility of using wind power for this function warrants serious investigation.

Wind power for electical loads has only a limited history in Africa. A few scattered battery charging systems have been and are currently in use for lighting and communication. There have been some attempts at operating electric pumps. The potential of increased use of small wind electric generators is probably fairly good and warrants more work. Large electric generators will be something to consider some time in the future.

RECOMMENDATIONS FOR ACTION

It is clear that much work remains to be done in order to develop wind power as a significant source of energy for Africa. These suggestions for action can be divided into recommendations for private enterprise, and those for donor agencies and African governments.

Private Enterprise

Private enterprise can best participate in wind power development in Africa through:

1. Technical Research and Development

Generally, water pumping windmill performance needs to be improved and manufacturing and maintenance costs reduced. Considerable improvements can be made in the following areas:

A. Development of a variable stroke device that could be added to existing water pumping installations at low cost to overcome starting torque problems. Such a device has the potential to double the volume pumped and greatly improve wind pumper economics.

B. Reduction of the overall cost and improvement of performance with improved rotors, transmission systems, and better matching of rotors to pumps. Many international researchers have taken the direction of using low solidity rotors to reduce weight and increase efficiency. Lighter weight, direct drive transmission systems running double acting pumps (generally for low lift) will also greatly improve pumping performance. While international efforts have made progress, American research and business capability could be a valuable resource. The Hydromite borehole pump developed by Climax Windmills (RSA) is an example of private industry making a significant contribution to Third World wind water pumping technology. Much work remains to be done on rotary and improved plastic piston pumps and pump leathers.

2. Reduction of the cost and increased marketing of wind data collection systems for use throughout Africa.

3. Collaboration with African businesses, cooperatives, or others to assist in the design and fabrication of appropriate wind pumpers, wind electric machines, and grain grinding attachments.

4. Collaboration with African businesses, governments, and institutions to provide maintenance training programs. Without such training, wind power efforts in developing countries will probably not have much of an impact.

5. Collaboration with African institutions to initiate wind power demonstration programs.

Donor Agencies and African Governments

Donor agencies and African governments can best develop wind power in Africa by collaborating in support of African institutions conducting wind power programs. Four points are of particular interest here:

1. Better wind data collection and assessment, training of personnel, and installation of new meteorological equipment will be required in many areas. An overall national wind energy assessment for most African nations is needed.

2. Surveys of wind power use in African countries are necessary in order to understand better the results and experience gained from past work. Specific reasons need to be determined for the many failures of wind pumps in the past, as well as ways in which successful wind technologies can be replicated.

3. Development of reliable locally produced wind systems for water pumping is a first priority, with grain grinding and electricity as further goals for wind power development.

4. In order to build the needed personnel infrastructure, wind technology development and maintenance training programs should be supported in cooperation with institutions such as universities, businesses, and production cooperatives.

SURVEY OF WINDPOWER ACTIVITIES IN SELECTED AFRICAN COUNTRIES

BOTSWANA

Water Resources. Botswana is a very dry country. Rain falls only for a short period of the year, so surface water sources are uncommon. In some locations hand dug wells are possible, with depths of about 25 m, but the more common situation is deep boreholes (100 m and more). Water levels are also falling as more wells are drilled. Well water is often quite saline and has a high grit content.

Wind Data. Little exact wind data is available at this time. Recent studies of the country by Carothers (1980) show values of 3.6 m/s (8.0 mph) and about 60 watts/meter at Ramonedi. Carothers shows full histogram data for Ramonedi, but the time period and length of record are not certain.

Present Uses. In the past, the Department of Water Affairs of the Government of Botswana has installed an undetermined number of imported South African water pumping windmills, mainly for cattle watering in remote locations. In more recent years Mono pumps run by diesel engines have been installed due to maintenance problems with windmill piston pumps. The cup leathers in the standard wind or diesel driven reciprocating pumps have been wearing out rapidly due to the gritty, saline water. The Mono pumps have been found to be far more reliable and have been chosen for most future installations by the Government. However, diesel fuel prices have risen, so the cost of running these pumps has become quite high. Thus, several institutions, as described below, have been working on wind machines to drive Mono pumps.

Research and Development. The Rural Industries Innovation Centre (RIIC) in Kanye took up the task of developing a windmill for Mono pumps in 1977. With financial and technical support from International Development Research Center (IDRC)(Ottawa) and Intermediate Technology Development Group (ITDG)(London), two basic models have been built and are undergoing careful tests. The first design used was the Filippini model, chosen for its relative simplicity and vertical axis orientation. The main problem found with this approach is that in order to make the Filippini strong enough to withstand high winds, its costs must be high. After three years of work it is likely this design will be abandoned due to the high wind problem. A second approach has been to use the low solidity ITDG design with a right angle gear drive and clutch. This design is presently under development. A wind driven Mono pump system was previously reported successfully operating in the North Cape region of South Africa in 1956.

Pelegano Village Industries has worked with RIIC to demonstrate a Filippini/tire pump system for lower head applications. As of 1978 the device was completed and was under test, but results are not yet available.

CAPE VERDE

Water Resources. This small group of volcanic islands off the coast of West Africa has very limited water resources. There are a number of wells on the island, but water levels are falling and there is evidence of saline water intrusion.

Wind Data. Wind measurement on Cape Verde extends back to 1915. Most of the early data are available through local meteorological services or the Ministry of Rural Development. The Portuguese government in Lisbon and the National Climatic Center in the United States have summaries of some of this data. Steering Committee on Wind Energy for Developing Countries (SWD), in their 1976 study of wind energy in Cape Verde, quote several more recent sources from the mid 1960's and early 1970's. Wind distribution data are listed for San Pedro (Sao Vicente) and Praia (San Tiago). Monthly mean speeds are listed for Mindelo and Sal. Typical values show an annual mean of about 5.5 m/s. The winds are reported to be from the northeast over 50% of the time and quite steady.

In 1978 more careful measurement began at the Praia Airport. Daily mean speeds were recorded 6 m off the ground in a well exposed coastal location. The data was reduced by Joop van Meel of SWD and listed by Blake. An annual average of 6.6 m/s was found. Distribution and mean power information was compiled indicating a mean yearly power of 210 watts/m^2, with a maximum of about 370 w/m^2 and a minimum of 65 w/m^2. July to September is a period of lesser winds.

While Praia may be indicative of coastal winds it is likely that hilltop or pass sites will have much more wind. Uberto do Fonseca, a Cape Verdian meteorologist is reported to have measured 17 m/s mean wind speeds at a mountain pass site on Sao Vincente over a six-month period. There is a variety of institutions involved in initiating new wind measuring programs. US Agency for International Development (AID) and the Dutch SWD are reportedly working with the Ministry of Rural Development to begin new wind data measurement programs for wind energy purposes. At the same time the Sahel Water Data Program AGRHYMET will be installing new anemometers for agriculturally related data for about 20 locations in the archipelago.

Clearly the wind energy potential looks good and it is now being carefully investigated.

Present Uses. For such a small group of islands, the amount of wind power usage is very high. The island of Sao Vincente has about 75 "multiblade" water pumping windmills. Some are imported, and some are produced locally. There are two small-scale producers of multiblade water pumpers on Sao Vicente - ONAVES Shipyard and Fabrica Favorita. The mills are basically copies of the Dempster or Aermotor type mills having about 2 m diameter rotors, a reducing gear drive, and oil bath lubrication.

The cost of the units is approximately US$1000. Most of these machines are used by local people for small garden irrigation. Repairs are made generally by the manufacturers.

In support of this local initiative SWD is reported to be working with the two manufacturers to improve the 2 meter design and develop a 4 meter design as part of a 3 year comprehensive program. USAID has also planned to support these operations by purchasing some of these machines and putting them on other islands.

Apparently unaware of the local manufacturing capability, Church World Services recently donated 25 Dempster 2 meter diam. machines to Cape Verde and UNICEF reportedly will soon provide 10-15 more of these machines to be used in a UNDP wells program. On Sal, an imported Dempster system in service for just three years was observed by Blake to have seriously and dangerously rusted and was no longer in service; blowing sand and salt had stripped all of the galvanizing from metal surfaces and corroded the underlying steel.

On the island of Sal there are approximately twenty saltwater pumping windmills made of wood. The wood, which is imported from Guinea, is used to make a four-bladed rotor of 3 meters in diameter driving an iron crank connected to a piston pump, lifting sea water up about two or three meters. Sea water flows to evaporation ponds where the salt is collected. The same type of mills are used on Boa Vista for lowhead fresh water pumping for agricultural purposes. These mills are one of the few "indigenous" uses of windpower in Africa.

Research and Development. There is presently a wide variety of research and development activities on wind power in Cape Verde for both water pumping and electricity generation. Most efforts are coordinated with the Ministry of Rural Development of the Government of the Republic of Cabo Verde. With funds from United Nations Development Programme (UNDP), several wind generators in the range of 5-10 kw were imported from the United States and Switzerland for demonstration and testing. Another UN project is looking at the feasibility of driving electric submersible pumps with wind generators. The French assistance group CIMADE has provided two French manufactured Aerowatt wind systems to Cape Verde; one to drive a Grundfos pump. CIMADE also intends to do an aerial survey for regions of excessive tree flagging (wind induced deformation) where there may be high wind potential. Feasibility of grid connection of wind generators has also been investigated. For diesel at its 1979 price of 68¢/gallon and the mean annual speeds found at Praia Airport in 1978, a grid connected wind electric system could pay for itself in six years (Blake). The wind potential of the Cape Verde Islands is encouraging.

EGYPT

Wind Data. Data collected by Dr. Mahmood Hegazi and reduced by William L. Hughes show modest wind potential along the Mediterranean coast west of Alexandria and good wind potential along the Red Sea south of Suez. Along the Mediterranean there is a highly seasonal wind varying from monthly average lows of roughly 2.8 m/s in the winter at Ras El-Hekma to mid-summer monthly averages of 6.4 m/s at Borg El Arab. At some locations and during some seasons these winds also had large hourly variations. At Ras El-Heckma, for example, winds during early autumn varied from morning highs of 3.6 m/s to evening lows of 1.4 m/s. Winds generally were from the North and West.

Along the Red Sea stronger winds prevail that may be suitable for power production for the electric grid. At Ras Ghareb monthly averages range from 5.3 m/s winter lows to summer highs of 7.3 m/s. Winds are generally from the West.

Research and Development. A prototype ITDG water pumping wind machine is now being tested in Egypt.

ETHIOPIA

Water Resources. Little information is available on water resources in Ethiopia. There are a number of surface water sources such as lakes and the Addis River in the Rift Valley. Many areas likely have fairly shallow hand dug wells. The Ethiopian Water Resources Authority is the most likely source for aquifer data and depth information.

Wind data. Accurate wind data are not available at this time, but wind energy availability can be expected to be moderate. Wind data have been collected at weather stations at many locations in the country. There is reference to a study by C.A. Munoz in 1974, entitled "Analysis of Wind Data in the Drought Affected Area in Ethiopia," for the National Water Resources Commission. This report and more recent data may be obtained from the Ethiopian Water Resources Authority.

Present Uses. A small number of imported commercial wind pumps have been used in the past in Ethiopia. Southern Cross mills were used at Maki and Zewai. Both have suffered serious problems over the years and in fact the one at Zewai has blown down. Taye (1980) reports problems with pump leathers wearing out in only a few months. He is now investigating plastic "leathers".

Research and Development. During the mid-1970's a variety of research and development programs was carried out, especially during the period of the "Development through Cooperation" program in 1974 and 1975. Karl Jensen of the Mechanical Engineering Department of Addis Ababa University designed and tested a number of wind pumps. Tests were carried out to refine prototypes for local production. Professor Gouin and Mr. Filippini of the Geophysical Observatory developed an experimental vertical axis, moderate solidity rotor. This work was continued at the Ethiopian Water Resources Authority with funds from IDRC, Canada, in 1977. The same model has also been tested by researchers in Senegal, Botswana, and Canada.

Starting in 1972, the American Presbyterian Mission at Omo Station installed a Dempster wind pump for garden irrigation. Over the next few years, Ted Pollock, Bob Swart, and other Mission personnel started a campaign of building small water pumping mills. Several more Dempster and Savonius mills, and many Cretan type sail wind pumps were built. The sail mills have shown the most promise. Several designs were simple, quite low cost, and local farmers began to use them to pump water out of the Omo river for vegetable garden irrigation. The mills were sold to farmers at a subsidized price. In 1975 Peter Fraenkel of ITDG in London visited Omo and made a number of suggestions on improving the mills, such as a larger rotor diameter and the use of double acting pumps. By the end of 1975, 26 of the "Polomo" mills had been built, and plans were made to build 75 more. The results of the latest work are not known. It has been learned from a variety of secondary sources that these mills did require quite frequent lubrication and were not considered very sturdy. The Appropriate Technology Unit of the Christian Relief and Development Association in Addis Ababa, which supported and documented the work at Omo, is believed to have ceased operation in 1978.

The most recent report on wind power development work in Ethiopia was presented by Teferi Taye of the Ethiopian Water Resources Authority at a conference on low cost water pumping in Botswana, November 1980. In the report he outlines development work underway on three fairly large (6-9 m diameter) horizontal axis water pumping mills and on the Filippini vertical axis mills. Prototypes have been built and are now undergoing a careful test program. Details of the mills will not be provided here, but it is interesting to note Taye's use, on the horizontal axis mills, of three large slender blades and a smaller set of starter blades on the same wind shaft.

THE GAMBIA

Water Resources. The Gambia is dominated by the river of the same name. The tidal area of the river is salty up to 240 km from the coast. Wells through most of the country vary from 5 to 25 m, with deeper wells to the east. Specific yields are in the range of 5 m^3/hr/m (drawdown).

Wind Data. Winds are generally quite low, with calms approximately 30% of the time, wind speeds over 5.4 m/s 6% of the time, and the remaining 64% between zero and 5.4 m/s.

Present Use. The only known use of wind power is the construction and testing of a 5 m diameter sail type wind pump design by R.D. Mann of the Gambian Christian Council. The mill was constructed and tested at the Yundum Experimental Station in 1977. The mill was to be used for small scale irrigation of vegetable plots in the dry season. The design and test results have been published by ITDG in London, and information on the status of the work since its construction is not available.

GUINEA

Water Resources. Guinea has plentiful but highly seasonal water resources. Annual rainfall ranges from 1150 mm on the border with Mali to 4400 mm at Conakry. Most rain falls during a six month rainy season from May-June to October-November. River flow and ground water levels rise and fall dramatically with rainfall. The water table can vary by 10 to 20 meters between the wet and dry seasons.

Wind Data. The wind energy resource in Guinea is small. Wind speed and direction measurements are routinely made and transmitted to Conakry at eleven stations of the "Direction Generale de la Meteorologie" in Guinea. The measurements are reportedly made at a height of 10 m but no indication of surface roughness or nearby obstructions are available. According to a recent study by VITA, the available wind data show that the windiest region, the coast, has windspeeds exceeding 4 m/s only 14% of the time. Isolated regions of higher winds may exist but are not now known.

Racine Bah of Intstitut National de la Récherche et de la Documentation de la Guinea (INRDG) in Conakry has also conducted a brief preliminary study of wind energy possibilities in Guinea. Based on 1979 data collected by the Direction General de la Meteorologie, calculations of annual energy production per square meter of rotor for 11 sites in various parts of the country indicate a mean for the sites of 17 watts/square meter (w/m^2), with a high of 29 w/m^2 and a low of 9 w/m^2. Obviously there is considerable variation, but the values are quite low.

Present Use. Bah discusses a successful Aermotor installation at Boke in the north coast area. Meteorological data indicate a mean power value of 13 w/m^2 for Boke, less than many sites in Guinea. Yet, the 3.6 m diameter machine is providing irrigation water to a local garden. Bah concludes that more work must be done on evaluation of this energy source, and the trial of more Aermotor machines in other favorable locations.

Two multiblade water pumping windmills are reportedly to be installed in the Northeast of Guinea for cattle watering; it is likely they are Argentinian machines.

Research and Development. Bah at INRDG has built a Savonius rotor. No details of active research are available.

This information is largely from a joint VITA/LIFE (League For International Food Education) survey of resources and potential uses of appropriate technology in Guinea undertaken at the request of and with the cooperation of the Government of Guinea.

KENYA

Water Resources. Most Kenyans rely on surface water sources or rain water collection. Lakes, streams, rivers and springs are common water sources for village use. Rain water collection is quite popular, but people revert to surface water in the dry season. In the arid northern region, shallow hand dug wells are more common. In some areas, however, deep boreholes are made for ground water, with depths in the range of 80-200 m.

Wind Data. Little exact wind data is available at the present time. Data summarized by one Kenyan manufacturer indicated approximate annual averages of 2.2 to 2.7 m/s in certain locations. However, Hilton of the University of Nairobi analyzed wind data in Kenya in 1975 and concluded that reliable wind energy resources are available in the area around Lake Victoria and in the flat arid northern region. D. J.K. Ng'ang'a of the Department of Meteorology of the University of Nairobi is also believed to be collecting Kenyan wind data.

Present Uses of Wind Power and Research and Development. According to Hilton and Opondo (1980), water pumping windmills have been used in Kenya for over 100 years. Australian, American, and British multiblade mills have been used, mainly in the productive farming areas, which are, incidentally, areas of fairly low winds. These mills have usually been superseded by diesel engines. As diesel prices rose in the 1970's, research began anew and has reached production levels at a few locations in Kenya.

Research began at the Department of Mechanical Engineering at the University of Nairobi with the work of Hilton and others. A number of Cretan type water pumping windmills were built, as well as a Savonius pumper and a horizontal axis mill with bamboo spars and sheet metal blades. Local production of these mills was intended.

Presumably in response to the University's work, the Christian Industrial Training Centre (CITC) in Nairobi began production of the Cretan sailwing water pumper. The program, with support from the National Christian Council of Kenya, was aimed at low-lift irrigation for small farms near the Tana and Daua Rivers. It is known that the South Turkana Agricultural Development Project in Lokori installed one in 1977 for irrigation pumping. It was still providing good service as of the latest report. However, the construction of the CITC mill has stopped, because of its "poor aerodynamic properties," according to Opondo. CITC may soon get back into production in collaboration with the University of Nairobi.

There are three other manufacturers of wind pumps in Kenya. At Mbita near Lake Victoria a production unit has been established at the Mbita Catholic Mission with assistance from a Dutch engineer. A 6 m diameter sheet metal rotor is being built for deep well pumping at a cost of US$ 2300. Efforts are underway to reduce the cost. The mills have been under test for two years with few problems. Secondly, at Kisumu, also near Lake Victoria, Plough and Allied Products is producing a metal water pumping mill similar to the Mbita design for a similar price.

In Thika, near Nairobi, Bobs Harries Engineering, Ltd. has recently begun production of four sizes of water pumping windmills under the trade name Kijito. The project has been carried out with considerable technical assistance from ITDG in London. The design is a modification of an ITDG design previously tested in Britain. The mills come in 12', 16', 20' and 24' diameter sizes. They are made from materials produced in Kenya, with the exception of bearings and oil seals. The multiblade rotors use fiberglass blades manufactured in Nairobi. A direct drive transmission transfers power to a reciprocating piston pump. Bearing greasing is required at six month intervals but Mike Harries, manager of the firm, is investigating the possibilities of self lubrication. Harries is also investigating the use of a variable stroke linkage, which would greatly increase the water pumped at a relatively small extra cost. Peter Fraenkel of IT Power reports, however, that to be economic, the key factor is maintaining system reliability and long life. Their work indicates that inertia pumps, double acting pumps, and variable stroke mechanisms tend to put such a strain on transmissions and bearings that system life is drastically reduced. Hence, such advanced systems are receiving somewhat less emphasis now. ITDG recently sent a machine design specialist, Paul Dawson, to help improve the design and production methods.

In light of the relatively short production history in Kenya, sales have been encouraging. The prices are lower than imported American or Australian windmills. Harries also provides installation service and a one year guarantee. As of November 1981, 40 Harries machines were installed and production rates are 1/week and expected to increase to 150/year in two years. A market survey done on Harries machines indicated a high demand for very small wind generators to trickle charge batteries. ITDG, under Bill

Wright and Dr. Hugh Bolton of Imperial College, is now developing an appropriate trickle charge generator and will field test it in Kenya with the intention that it be manufactured there.

Opondo also reports installation of another machine in Kisumu designed by Carl Jensen. The rotor involves three large aerofoil blades, and nine smaller high pitch blades to aid in starting.

SWD reports that they have been approached by the Ministry of Energy to do a major study on wind energy. Plans have not yet been finalized, but the present objectives include review of wind data and present activities toward policy formulation.

Finally, the University of Nairobi Wind Energy Technical Panel has initiated a new wind research program. Funds are limited but a focus has been placed on variable stroke transmissions, windmill towers, and low cost rotors.

LESOTHO

Water Resources. In the lowland areas of Lesotho the water resources are streams or deep boreholes in the sandstone rock. At the higher mountain elevations, boreholes are rare and water is found in springs or streams. A long dry season means many of the surface water sources are only active about one half the year.

Wind Data. Except for a few locations, the winds in Lesotho are poor to moderate for most of the year. Lowland winds are around 2.2 m/s (5 mph) annual average, while mountain locations have winds around 3.6 m/s (8 mph). Certain well exposed locations have mean speeds up to 6 m/s annual average. The winds are highly variable from one site to another due to topography. There is a "windy season" at the end of the dry season and as the rains return. Extremely high winds (over 35 m/s) are not uncommon during the "windy season". Wind systems must be sturdy enough to take these strong winds, so the costs can be high. At the same time, winds are low much of the year, giving a low return. Using water pumping windmills just for irrigation in the dry windy season may make good sense. Wind data can be obtained from the Hydrological and Meteorological Services Branch of the Ministry of Water, Energy, and Mining in Maseru.

Present Uses. The Ministry of Rural Development Water Branch has installed around 50 South African windmills for borehole pumping for village water supply. These have encountered a number of problems and some are not in service. Windmills were often sited in poor locations. The systems were planned based on manufacturer's pumping charts of winds in South Africa, and water outputs were often lower than expected. The galvanized steel storage tanks were often undersized, causing dry periods, which resulted in wind pumps having a bad image. Some wells have also gone dry, causing pump leather damage. Wind pump maintenance has on occasion been lacking, causing unnecessary breakdowns. It is believed that for all these reasons the Ministry of Rural Development is turning away from windmill use.

Research and Development. There has been little research and development work due to the close proximity of South African manufacturers and distributors of water pumping windmills. However, the Thaba Tseka Integrated Rural Development Programme has conducted a wind power program for the mountain areas. Wind speeds at various sites have been measured, and two commercial machines and one locally built Savonius rotor are being tested. One commercial wind generator was tested as a possible source for lighting of local clinics. The machine has suffered a number of electro-mechanical problems due to occasional high winds. Repairs have been made several times, but the machine, a 24v, 200 w Windcharger by Winco, has not proven reliable. The commercial water pumper is being used in a two stage pumping system, with a hydraulic ram lifting water part way up a hill and the windpump carrying it the rest of the way over the hill to a village. Tests have not been completed. The Savonius rotor was destroyed due to high winds and may be rebuilt. Thaba Tseka staff have reviewed wind data for other parts of Lesotho and done economic evaluations of wind and other local energy sources.

The Thaba Khupa Ecumenical Farm Institute operates a metal working shop for training of young people and production of farm tools. They have built a Savonius rotor that is now being tested at a lowland location as part of a garden irrigation scheme.

MALI

Water Resources. The main water resources in Mali are the Niger and Senegal rivers, and fairly shallow hand dug wills in the bordering terrain. Windpumps near Sama have pumped wells dry during the dry season.

Wind Data. Generally the available wind energy increases greatly from the south where it is quite low (1-3 m/s) to the north where it reaches 5 m/s (annual average). Gao, near the bend in the Niger River, has a mean wind speed of about 4 m/s. Local wind data has been analyzed by Kone at the Ecole Nationale d'Ingenieurs du Mali. The main disadvantage with the wind power possibilities in Mali is that the southern area, where most of the people live, is the area of lowest wind. Paulissen and Van Doorn, in their Sahelian wind energy study, have suggested the Niger valley from Segou to Gao as a populated area with moderate winds and good water resources.

Present Uses. In the 1950's 35 Aeromotor and Game water pumping windmills were installed in the Gao region. After only a few years all had stopped working. In the early 1960's many were put back into service, but maintenance did not keep up and they stopped again several years afterward. Reportedly, several Catholic missions have wind electric systems, likely of French origin.

In May 1980, a Sahores type water pumping windmill was installed at a community garden in the village of Sama near Segou. The work was carried out by two men of the Bozo tribe with assistance from a local Peace Corps Volunteer named David Benafel, Father Jean Plasteig of the Catholic Mission in Segou, and some technical support from VITA. Father Plasteig has built over 20 of the units in his workshop using primarily materials such as wood, bamboo, sheet metal, etc., but has also experimented with aluminum construction. He now conducts training courses for villagers to come and build machines in the shop. David Benafel applied for and received a grant from VITA in May 1981, to build six more machines in Sama, Dioro, and Tibi. Results have been encouraging, with several of these windmills now in place. Although there have been some breakdowns, primarily due to the use of weak towers to support the machines, in many cases the machines were repaired and maintained by the villagers themselves. However, help from Peace Corps technicians was needed in other cases. VITA will be funding a second phase where maintenance training is to be emphasized. Technical support and performance evaluation for these machines is being provided by the Laboratoire D'Energie Solaire in Bamako and VITA.

Research and Development. Professor Bectine at Ecole Nationale d'Ingenieurs has built a 13 m-high Savonius rotor with his students and has installed it as a testing unit near Bamako. Unfortunately, his experimental results gave anomalously high performance.

The Laboratoire D'Energie Solaire at Bamako with technical assistance from Solar Energy Research Institute (SERI) and VITA is conducting a study of wind power in several parts of Mali. Wind data is being collected and design work and performance testing focusing on the Sahores type multiblade machine is continuing. Tests to date indicate good rotor performance. The rotor is 3 m in diameter, has 16 curved metal blades on bamboo spars with four common feathering cables - 48% solidity. The research focus is now turning towards the transmission and linkage.

MAURITANIA

Water Resources. Water is a problematic commodity in Mauritania. The only major surface water is the Senegal River at the southern border. Wells of depths of from 5 to 100 meters are sparsely scattered through the country. The aquifer that is pumped to serve Nouakchott, the capitol, is expected to run dry in less than 10 years.

Wind Data. Winds are generally fairly strong on the coast, and decrease to the east and south. Ten years of records for Nouakchott show an annual mean of 4.8 m/s but this drops to about 2.6 m/s at Kiffa and 0.85 m/s at Matam, Senegal, just over the Senegal river from Mauritania. In general the coastal areas have good wind energy available.

Aerowatt, a French wind power firm, was interested at one point in installing additional wind measuring equipment in Mauritania but results are not available.

Present Uses. No active wind projects are known of in Mauritania at this time, but a number of Game multiblade wind pumps were used during the French administration. These have all suffered mechanical breakdowns, probably due to lack of maintenance. Blowing sand is a significant factor in Mauritania, so only machines that are well suited to these conditions can be used. On water pumping windmills, regular lubrication of the tail hinge may be necessary or the mill won't be able to protect itself in high winds. All wind machines used on the coast will require repainting or other special attention to resist salt air corrosion.

Research and Development. No activities are known at this time, but VITA Volunteer consultant William Hughes has recently done a study on wind power possibilities in Mauritania. Much of the above information is derived from his report.

SENEGAL

Water Resources. Water resources in Senegal have been quite accurately assessed. Resources include the Senegal River basin and fairly good aquifers through most parts of the country. A typical borehole depth is about 20 m. Rainfall is highest in the southern part of the country, decreasing towards the north.

Wind Data. Senegal has good winds on its north coast, with only moderate winds inland and to the south. Annual averages on the coast are about 4 m/s (according to Paulissen and Van Doorn). The period of strong northerly trade winds is from approximately mid-November to mid-June. During this time, which is also the dry season, daytime winds are often at a mean of 8 m/s. Paulissen and Van Doorn in their study of wind energy for the Sahel region have concluded that the North coast area and the Senegal River basin are areas of favorable and moderate wind energy possibilities, when both water and wind resources are considered.

Recent work by Le Gourieres supports Paulisson and Van Doorn's conclusions. North coast winds of 487 kwhr/m^2 year (56 w/m^2) were measured at Dakar and 442 kwhr/m^2 year (50 w/m^2) were measured at St. Louis but winds of only 164 kwhr/m^2 year were observed at Kaolack. Winds usually are from the north and west and vary only slightly with season.

Present Use. Paulissen and Van Doorn have reported some experimental use of the "Sahores" mill in Senegal. The results, as in Upper Volta, were that the mill did not stand up well. Caritas-Senegal is reported to have fairly recently installed two wind electric machines to drive electric water pumps. AFRICARE is reported to have received some funding for a Savonius rotor project. Also Lay Volunteers International Association has installed 4 "Grosseto" water pumpers near Thies (Peycouk Project). These machines start in a 1.6-1.8 m/s wind and each can provide domestic water supply and irrigation needs for a village. The engineer in Peycouk is Giuseppe Deccaria.

Research and Development. A number of groups have been experimenting with small locally made rotors. The Savonius and Filipinni mills have been quite popular. D.V. Nguyen at the Ecole Polytechnique in Thies had done wind tunnel testing of Savonius and Filipinni rotors of various geometrical configurations. The extent of any full scale construction is not known.

The newly formed Centre d'Etudes et de Recherches sur les Energies Renouvelables (CERER) at the University of Dakar has tested a Savonius rotor that was built by the semi-private enterprise Societe Industrielle des Applications de l'Energie Solaire (SINAES). There have evidently been some technical problems, especially in high wind protection of the rotor (it has been damaged once). SINAES was created by the Senegalese Ministry of Rural Development and Hydraulics to provide technical support services to the Government. The University has also built several large Savonius rotors and a 15 m Giro/Savonius mill combination.

SOMALIA

Water Resources. Somalia has an average annual rainfall of 329 mm/year with no more than 500 mm/year in any region. Rainy seasons are March-May and December. In the four refugee regions, camps in the Gedo region have adequate water from the Juba River, camps in the Belet Van district of Hiran have adequate water from hand dug wells, camps in the Northwest region rely on water attained from wells dug by hand in the dry river beds, and in the lower Shebelli region, the Shebelli River went dry at Coriolei as of February 1981. UNICEF, funded by United Nation High Commission for Refugees (UNHCR), plans to begin drilling 150 wells in refugee camps in all 4 regions in March 1981.

Wind Data. Two detailed studies of the wind resource in Somalia have recently been released by Faculty members of the National University of Somalia in Mogadishu. Both show an excellent wind resource. D'Angelo et al show country-wide mean wind speeds of roughly 5 m/s. At Hargeisa mean wind speeds of 7.6 m/s were recorded. The work by Pallabazaar, though more detailed and encompassing 19 stations, is flawed by the use of anomalously large height correction factors. When these are divided out his values are generally comparable to those of D'Angelo et al. Pallabazaar does discuss the data collection process and points out that data for some sites consists of instantaneous readings, some of totalizers, and that varying sampling methods were used. A more consistent and comprehensive analysis is needed.

Pallabazaar also discuss in some detail the seasonal variation of the winds. The four seasons consist of (1) Jiilaal - from mid-December to mid-March with monsoon winds from the northeast, (2) Gu' - from mid-March through May with irregular winds and rain, (3) Xagaa - from June to September with humid southeast monsoon winds, and (4) Beyr - from October to mid-December with irregular winds.

Finally, D'Angelo includes a discussion of pumper economics showing an advantage for wind over diesel.

Present Uses. A number of multiblade windmills for water pumping have previously been installed in Somalia, but most are no longer in use due to a lack of spare parts and trained and responsible maintenance, and due to the low energy prices during the 1950's and 60's.

Research and Development. VITA has proposed to the UNHCR to erect five windmills near the Hiran region refugee camps for water pumping. Simultaneously, National Refugee Commission personnel and local refugees would be trained in the operation and maintenance of these machines. The system would be evaluated for possible dissemination elsewhere.

Abdirazah M. Bihi, dean of the Faculty of Engineering at the National University of Somalia, has proposed a project to USAID/Somalia to install and test five wind pumps in various parts of Somalia. Three of these will be rebuilt from existing non-functional windmills in Somalia. The emphasis will be on developing local operation and maintenance capabilities, evaluation of the wind resource and windpump economics, and possibly development of local manufacturing capability. Outside technical assistance will be provided in part by Peter Bruijs with Experience, Inc., and Bud Kellums with USAID Water Development, and probably VITA.

SOUTH AFRICA

Water Resources. The water resources in South Africa have been carefully explored, analyzed, and tapped. The Vaal and Orange Rivers are a major surface water source but are heavily used. Boreholes are the major water sources in the country. As of 1973 there were about 600,000 boreholes in the country with about 250,000 serviced by wind or motor pumps in the rural areas.

Wind Data. Winds in South Africa vary, generally speaking, from moderate to quite good. Coastal regions will average around 4 m/s annually. The vast plateau through most of South Africa has mean wind speeds around 3 m/s. A figure of 7.3 mph (3.3 m/s) has been derived as an overall country average. While these averages may seem low, Bloemfontein data shows an annual average of 6.3 mph (2.8 m/s) but an energy pattern factor of around 5. Thus energy available is considerably higher than the annual averages might indicate. Quite good wind data, including frequency distributions and year to year variability figures, are compiled by the South African Weather Bureau in Pretoria. (Climate of South Africa, Part 12, Surface Winds, South African Weather Bureau, Pretoria, 1975).

Present Uses. Present uses of wind power in South Africa consist mainly of commercial water pumps. There are two manufacturers in South Africa and many thousands of mills in use. As with any piece of machinery there have been some breakdowns, but there are a remarkable number of working windmills. Parkes (1974) in his study of wind power in Tanzania estimates that as of 1960 there were 185,000 windmills in South Africa. Farmers and ranchers depend heavily on wind for cattle watering and domestic water supply. The use of wind pumpers has not fallen off as it did in the United States, mainly because the price of diesel fuel has remained high, and there has not been an emphasis on rural electrification as in the United States.

The market is expected to continue to be good. Climax Windmills has recently added a new, well engineered direct-drive 5.5 m (18') diameter mill. Climax also produces towers and pumps and has recently introduced an innovative "Hydromite" hydraulic borehole pump that can allow the windmill to be placed on high ground away from the well, giving improved efficiency and easy maintenance. Southern Cross, the Australian firm, has a manufacturing plant in Bloemfontein producing a variety of mills, towers, and pumps. Windmill prices are, in general, considerably less than those in the United States or Britain. There has been work with wind driven Mono pumps (see Botswana) in the past.

Although not as much work has been done, there is growing interest in the use of electric wind generators in South Africa. The American made "Windcharger" by Winco has been distributed by a Pretoria firm for a number of years. The number of units installed is not known, but the distributor says that a fair number are in use in the mountainous area of western Transvaal. This dealership has been bought out recently by a firm called Semiconductor Services in Johannesburg. The same firm is also developing its own generator for production in South Africa. Standby Emergency Power Systems in Johannesburg is a distributor for Dunlite, the Australian wind generator. Sales have not been very high as yet.

Research and Development. Compared to the production activity on water pumping windmills, little research and development is going on. The Council for Scientific and Industrial Research has competent wind engineers and is known to be working on fiberglass blade technology. The only other known activity is some experimental work on Savonius rotors by the Environmental and Development Agency in Marshalltown.

SUDAN

Water Resources. Rainfall varies from 76 mm/year in the Northern deserts to 180 mm/year at Khartoum to 1122 mm/year at Wau. Groundwater levels range from 10m at Kassala to 30 m depth and more at Gezira. Surface waters include the Nile, Gash, and other rivers. Ground and surface waters increase considerably during the summer rainy season.

Wind Data. Wind data compiled in a report, Memoir no. 7, by Y.P.R. Bhaldrum of the Sudan Meteorological Service in 1964 and presented in part by Dr. Hamid and SWD indicate a moderate to good wind resource. Average wind speeds of 4.3 m/s were seen at Khartoum. These winds remain fairly steady throughout the year. Winds increase to the north of Sudan but are comparable in magnitude throughout the central and northern parts of the country. Occasional high winds accompanying thunderstorms and in "haboobs" (desert whirlwinds) necessitate strong towers.

Along the Red Sea Coast selected sites have steady sea breezes of 4-7 m/s during most of the daylight hours. Further data collection throughout Sudan has been proposed by Hamid and SWD.

Present Uses. Nearly 100 5 m diameter British multiblade windpumps were installed in the 1950's for borehole pumping for village water supply in the Gezira region. None are now working due to a lack of spare parts (the manufacturer has stopped production) a lack of proper maintenance, and questionable economics. A 1979 economic analysis by the Gezira board found the wind system to be more expensive than a diesel one primarily due to the need for large overhead storage tanks. Pumping needs are now met by diesel systems, but the economics have likely changed considerably in light of the 1979 oil price increases. Mono pumps or turbine type pumps are now more common than reciprocating piston pumps due to problems with piston pump leathers wearing out rapidly. Dust has been cited as a problem with wind pump use in Sudan. Highly reliable wind pumps that are well sealed against dust will be required. Stuart Wilson reports that Australian mills were being considered for a second attempt at using commercial water pumps in

1975. The National Council of Research was considering using two Australian mills at an experimental site at Soba.

Research and Development. The only known activity in research and development in wind power is a study carried out by the Department of Mechanical Engineering of the University of Khartoum in 1975 where a prototype design was outlined. Wilson does suggest that small electric wind plants could play a significant role in village development, but this evidently has not been implemented to date. He also suggests an investigation of lower cost sail-type water pumpers.

In cooperation with SWD, Dr. Hamid proposed in July 1980, a Wind Energy Center at the Energy Institute (part of the National Council for Research) in Khartoum to design, develop, and test water pumping windmills suitable for manufacture in Sudan. Reportedly, the project has yet to get off the ground because of various delays in Sudan.

TANZANIA

Water Resources. In respect to water resources, Tanzania can be divided into two regions, with an imaginary line from the northern tip of Lake Malawi to the northern coast of Tanzania. Areas to the south of this line have plenty of surface water sources such as streams. To the north of the imaginary line the climate can be described as semi-arid. With the exception of lake areas, wells are common water sources in the north. Certain areas such as Shinyanga near Lake Victoria have a growing number of hand dug wells, mostly under 10 meters depth. In the Arusha region, water tables are considerably lower, down to 200 ft. or so.

Wind Data. Parkes (1974) has done extensive work compiling wind data records from totalizing "wind run" cup counter anemometers, pressure anemographs and Beaufort wind estimates for many sites in Tanzania. Counter cup "wind run" data are available for 60 sites. Wind frequency distribution curves have been derived from pressure anemograph records at five sites and Beaufort wind scale estimates at 13 sites. The data obtained at certain sites with several types of records are not quantitatively consistent, and thus the overall reliability of the data, especially the Beaufort distribution curves, is uncertain. Weir (1979) has done an analysis of Parkes' (1974) data but the report is not available at the present time. Based on Parkes' data, however, the wind power potential can be roughly categorized as moderate. Areas close to bodies of water will have good potential. At the east coast the northern and southern extremes around Lindi and Tanga have good winds, but the central coast around Dar es Salaam has only moderate winds. The western lake regions around Kigoma and Mwanza (Shinyanga) have relatively good steady winds. The central plateau around Dodoma has good winds at certain times of the year but quite low at other times. Other central areas such as Arusha, Moshi, and Morogoro have relatively low winds.

The University of Dar Es Salaam has conducted research on developing simple low cost wind energy evaluation devices. Weir (1979) has developed a multi-cup counter device to estimate wind frequency distribution. Reichel

(1977) has developed a low cost wind frequency recording system. Both devices are experimental.

While there remains plenty of work to do, Tanzania has made good progress in evaluating wind power potential.

Present Uses of Wind Power and Research and Development Activities. Tanzania has been one of the most active countries in Africa in developing wind power machines. Activities have involved the use of imported Australian water pumping mills and more recently the development of locally built designs by a variety of institutions.

Parkes (1974) reports about 30 of the imported multiblade water pumping windmills in Tanzania, mainly in Shinyanga and Dodoma regions. Most were installed many years ago, but only about one third are still in use due to a lack of spare parts and in some cases saline water intrusion. Parkes states that most installations did work well for about ten years, but quotes a source in the Singido region stating that the machines were never reliable. In the late 1960's and early 1970's about ten more Australian mills were installed in various parts of Tanzania and were working well, providing village water supply or cattle watering.

In the early 1970's, F. Van de Laak of the Shinyanga Shallow wells project reportedly worked on the Brace Savonius rotor and some other locally built designs, but never developed any dependable designs. After Parkes' report was completed, several institutions, including the Faculties of Agriculture (Morogoro) and Engineering (Dar Es Salaam) and the government Ministry for Water, Power and Minerals (MAJI), began wind power research and implementation programs. MAJI began by installing some Comet wind pumps in Dodoma. Later a priority was put on designs that could be produced in Tanzania. The MAJI workshop in Ubungo built a 6 m-diameter multiblade mill driving a Mono pump through a spare truck axle. MAJI also supported work on the Arusha windmill (described below). Reichel (1978) reports that in 1977 MAJI began a project, with assitance from Australia, to install 130 Southern Cross wind pumps in a variety of locations in Tanzania over a three year period. As of January 1982 about 100 had been installed.

The Faculty of Agriculture at Morogoro has developed a large Cretan Sail type mill driving a grain mill. No exact details are available, but the development is interesting because it is the only known attempt in Africa to harness wind to grind grain. Grinding was one of the first and one of the most widespread uses of windpower, but little work has been done recently. The number of diesel-powered grain grinders in Africa is large and a substitution of wind power could be quite important.

The Mechanical Engineering Department of the University of Dar Es Salaam has constructed several water pumping windmills. A "Pedersen" fan mill with a 6-blade 3.6 m-diameter rotor drives a piston pump for irrigation at the Tanzania Food & Nutrition Center in Dar Es Salaam. The Department has also completed design and construction of a 4-m diameter "Protzen Sumai" rotor, which according to Reichel (1978) incorporated a "variable speed" gear drive.

The Electrical Engineering Department has built several small windmills, including a Savonius and a horizontal axis design using a local hardwood blade. The Department has also tested a Bosman 400 w and a Bruemmer 1.2 kw wind driven generator. Reichel (1978) also reports that the Department completed a feasibility study of windpower for rural electrification, based on a 45 kw village power station.

Since 1976 the Arusha Appropriate Technology Project has been working on windpower for a variety of uses. In 1977 a booklet was published by Volunteers in Asia and VITA giving plans for the all metal wind pumper. The rotor consists of six sheet metal blades arranged to make a 5 m diameter up-wind rotor. The original design had a speed-reducing gear and "rocker arm" crank drive. A manually operated brake was included. At 5.4 m/s (12 mph) the device was rated to pump 2.3 m^3/hr with a 5 cm cylinder on a 55 m (180 ft.) head. The device went into production at an Arusha cooperative, Ujuzi Leo Industries. About ten of the units were installed. Reichel (1978) reports that there were problems with blade bending, and serious damage to some units.

Since the publication of the manual, the transmission, brake, and tail have been considerable modified. The reduction wheels have been eliminated, the tail lengthened and set to provide automatic furling, and an improved shaft brake designed. The original design required frequent maintenance, but has been improved with sealed bearings. The improved design also has a front extension pipe on the rotor and radial tensioning wires to strengthen the rotor.

Production cost in 1980 was about $1,925 in a kit form. There have also been at least two later generations of the Arusha machine. Wolfgang Wassertahl, a German volunteer, began work on an aluminum blade design. Also SWD reports other machine modifications similar to the Dutch WOT design.

This is the only known production unit in Tanzania, but it has been having difficulties. Funds to purchase manufacturing tools have been delayed and this has seriously hampered production capabilities.

The AATP has also tested a home built wind electric generator and a Savonius rotor. Work has also been done on an attachment to the Arusha windmill to provide mechanical power for well drilling and a second attachment to power small grain grinders.

The Maryknoll Fathers in the Mara region, with the assistance of SWD, did a windpump feasibility study in 1977. They found modest highly seasonal winds that would be useful for water pumping. Significantly, wind energy was greatest during the dry season. Preliminary economic analysis indicated commercial windmills could compete favorably with diesel or electric pumps. Locally made windmills could be even better. A pilot windmill construction program was proposed but reportedly has not gotten off the ground.

TUNISIA

Wind Data. A study in 1978 by Association pour le Développement et l'Animation Rural (ASDEAR)(Tunis) and SWD (Holland) gives wind data and makes some preliminary conclusions on good wind locations in Tunisia. Frequency histogram data and annual energy avialable are calculated for 11 sites covering most areas of the country. Histograms show strong winds, but energy calculations show a maximum or 214 kw hrs/m^2 year (25 w/m^2) at Gafsa and a minimum of 67 kw hrs/m^2 year (82/m^2) at Tozeur. Such calculations show fairly low winds, but nothing is known about the length of record, means of data recording or exposure of the anemometers. Winds are highest in the spring. The report also indicates, in a preliminary analysis, that the northern half of the country will generally be windier than the south.

Present Uses. The study by ASDEAR and SWD reports the existence of about 1200 imported multiblade windmills for water pumping in Tunisia. These were installed some time ago at state farms, public wells, and on private farms. A large number of these are not in service at this time. The report also indicates the existence of a small number of wind generators for lighting and battery charging.

The village of Hammamet on the northeast coast was surveyed in detail. Imported water pumpers began to be used in the 1920's and by 1960 about 200 had been installed. After that time new installations slowed due to government subsidies for electric power and diesel pumps.

The units installed included open gear models by Samson, Aermotor, Dandy, and others. There were also some oil bath lubricated Aermotors. Typical output for the 3.6-4.8 m diameter machines was about 50 m^3/day from a depth of about 15 m head. At the time of the study (1978) about 25% were being used, 6% were repairable, and 69% were not repairable. Problems in the failure of the mills were: storms (34%), pump wear (23%), gear wear (17%), lack of general care (13%), and other (13%). There were at one time 12 windmill maintenance people in the village. Parts were scavenged from damaged windmills in various parts of Tunisia. Some repairers remain there, but spare parts are hard to find or not available. Most of the models are no longer manufactured. It is interesting to note that the open gear models suffered more gear and bushing wear over the many years of service in sandy conditions than the oil bath models.

The study concluded that a major attempt to revitalize these mills will have limited success because of the age of the machines and lack of spare parts (except for oil bath Aermotors), and that repair of these heavy units would be expensive. However, the towers are in good shape generally. The study recommends importation of spare parts to repair the oil bath lubricated Aermotors and the development of new windmill heads to be put on the old towers.

Research and Development. Following up on the conclusions at Hammamet, ASDEAR, with SWD and Rural Engineering Research Centre, has begun to develop new windmill heads. They wanted a lighter machine with less maintenance and higher efficiency in different wind conditions. An all-steel model developed at Twente University in Holland was adopted. The unit features the use of locally available steel, a light sheet metal rotor, a crank/

connecting rod transmission (without gears), sealed bearings, and nylon bushings. The windmill was to be tried with two new pump models--a typical cylinder with a controlled leak piston, and secondly a new membrane pump. Efforts were to be made to work with windmill repairers in Hammamet. As of April 1981 three prototypes were built. Progress from there is uncertain. Aermotor repair success is also uncertain.

THE ASDEAR/SWD study also outlines an economic comparison of the improved windmill to electric pumps and diesel pumps. The conclusions are that in areas where electric power is available, it will likely be the more attractive option, but in more remote areas wind will be the best choice.

UPPER VOLTA

Water Resources. While no great problems should be expected in finding underground water in Upper Volta, no exact data are available at this time. The Comite Interafricain d'Etudes Hydrauliques (CIEH) in Upper Volta has conducted a number of surveys and underground water data are available through them. The Volta River does provide surface water.

Wind Data. The winds in Upper Volta are generally weak. Annual means are likely in the range of 2 m/s (Paulissen and Van Doorn). The availability of wind energy is generally greater in the northern part of the country. Exact data are incomplete, so there may be specific locations with greater wind. Wind is quite variable throughout the year.

Present Uses. Very little information is available on windmills in use in Upper Volta. Paulissen and Van Doorn report the use of several Aermotor and Game multiblade wind pumps. Some of these have failed due to a lack of maintenance or wells running dry. Also mentioned by Paulissen and Van Doorn are several Sahores locally built multiblade mills that were tried in Upper Volta. These were found to be not rugged enough for use in the country.

Research and Development. There is no known on-going wind energy research at this time.

ZAMBIA

Water Resources. The ground water situation in Zambia is generally quite good. Drilling work totals 4500 m per year. Typical small well diameters are 15 cm with an average depth of 55 m. Drilling is carried out by a number of private companies and the government Department of Water Affairs. Inventories show 3000 borehole wells in the country as of 1970.

Wind Data. Wind speeds are generally low in Zambia with typical mean speeds of 2-4 m/s, depending on the location. Data are being collected at a number of sites by the Zambian Meteorological Department. The wind is highest during the dry season.

Present Uses. Many (several hundred) of the multiblade type wind pumps are in use in the Lusaka district. There are three distributors of imported Australian and South African windmills. These are used by commercial farmers for cattle and domestic supply and by the Department of Water Affairs.

Some of these windmills have fallen into disuse due to a lackof changing oil, parts theft, and a poor spare parts infrastructure. According to one recent resident of Magoye, Family Farms Ltd. has, on a limited basis, been manufacturing small multiblade water pumping windmills, towers, and pumps for cattle watering and small scale irrigation. These mills are mostly being used for low-lift applications, such as pumping out of streams.

An economic analysis carried out by the Technology Development and Advisory Unit (TDAU) shows a cost advantage of the larger (7.6 m) commercial wind pumps compared to diesel pumps in Lusaka (3.5 m/s annual average) at the present time. As diesel prices rise, small diameter mills will become cheaper than diesel as well.

Research and Development. There is little research and development work going on at this time, but a recent meeting of a wind energy group was coordinated by TDAU. The group, involving commercial distributors and the Ministries of Agriculture and Water Affairs, felt there should be increased use of wind pumps for cattle watering and community water supply, with an emphasis on solving the previous problems. Local production of wind pumpers is an objective for the near future.

ZIMBABWE

Water Resources. Water resources are good in Zimbabwe. There are many surface water sources. According to a recent study on ground water resources in Africa, there is almost no area where the well yield is less than 1/2 m^3/hr.

Wind Data. VITA has no information at this time on wind data in Zimbabwe other than impressions reported by Stuart Spence in a recent paper. Winds are generally "low" and during some months of the year there is virtually no wind at all.

Present Uses. VITA has no exact data on the number of windmills in Zimbabwe. One author has seen several imported South African multiblade wind pumps in use in the rural areas. There are undoubtedly a number of these at commercial farms. Local manufacturing capability, according to Rev. Brian MacGarry, is being developed.

Research and Development. There is only a small amount of research and development on windmills in Zimbabwe. Some work is underway at the Institute of Agricultural Engineers (IAE) near Salisbury. Three small low-cost wind systems (Cretan, Savonius, multiblade) have been constructed. Numerous mechanical problems have occurred, and the designs are being modified. Most of the work concerns water pumping but an alternator was tried on the Savonius rotor. Spence at IAE has defined a goal to develop a competitive water pumper costing about Z$2500 for a 3.6 m diameter rotor, 10 m tower, with pipe and fittings for a 40 m borehole, expecting an output of 3000 l/day in mean speeds of 3 m/s.

A metal work training program at the Bethlehem Mission Society at Gwolo offers training for young people through the design and development of rural technologies including wind machines for water pumping and electrical generation. The exact type of designs or results to date are not known.

NOTES

Djibouti. In July 1981, SWD carried out a feasibility study for the German Technical Aid Organization G.T.Z. No results are yet available.

Guinea Bissau. No formal studies of wind potential have been done. Although most of the country has low wind, there may be some wind potential on islands off the coast, the Bijagos. A maximum wind speed of 37 m/s has been recorded on the island of Bolama.

Malawi. There is currently no active windmill program. A few water pumping windmills have been installed but generally light winds are believed to limit the overall potential for such technologies.

Morocco. Northwind Power Company reportedly has installed a wind-electric system at a remote telecommunications site. No active development programs are known.

Nigeria. A few isolated pumping stations have been installed in some coastal areas of the south and in the northern part of the country. Some of these installations, as in Badagry and some other coastal areas near Lagos, were installed over 25 years ago and have since been abandoned. Although a few Savonius rotors have been built at universities, there is little active windmill work in progress.

Seychelles. The Seychelles have just begun a 20 year program to achieve as much energy independence as possible. Investigation of the potential of wind for both water pumping and electricity production is planned. With the mean wind speeds of 4 m/s recorded 10 m off the ground at Seychelles Airport, northwest from November to March and southeast from April to October, there is moderately good wind potential.

Zaire. Winds reportedly rarely exceed 3 m/s which limits the use of wind machines to special cases.

These notes are from the respective National Reports submitted to the United Nations conference on New and Renewable Sources of Energy, Nairobi, Kenya, August 10-21, 1981.

CONTACT LIST

For entries marked with a star (*) little information is available, but these institutions are believed to be carrying out wind energy research or implementation activities.

BOTSWANA

1. <u>Rural Industries Innovation Centre (RIIC)</u>
   Private Bag 11
   Kanye
   Botswana
   Contact: Max Ewens, Eize de Vries
   Activity: Development of wind powered machines for monopumps

2. <u>Pelegano Village Industries</u>
   P.O. Box 464
   Gaborone
   Botswana
   Contact:
   Activity: Testing of Filipinni rotor pump

3. <u>Government of Botswana</u>
   Meteorological Services
   P.O. Box 10100
   Gaborone
   Botswana
   Contact: J.B.S. Dephaha
   Activity: Wind data collection

4. <u>Government of Botswana</u>
   Department of Water Affairs
   Gaborone
   Botswana
   Contact:
   Activity: Use of commercial windpumps for water projects

REPUBLIC OF CABO VERDE

1. <u>Ministry of Rural Development</u>
   P.O. Box 66
   Praia
   Cape Verde Islands
   Contact: Horacio Soares, Joop van Meel
   Activity: Implementation of wind energy programs, including wind energy measuring and windplant testing

2. ONAVES Shipyard
Mindelo
Sao Vicente
Republic of Cape Verde

Contact: Sr. Augusta Duarte - Foreman
Sr. Estevao dos Anjos Duarte - windmill designer and builder

Activity: Manufactures 2 m windmills

3. Fabrica Favorita
Mindelo
Sao Vicente
Republic of Cape Verde

Contact: Sr. Matos

Activity: Manufactures 2 m windmills

EGYPT

1. Bassissa Village Project*
American University of Cairo
Cairo
Egypt

Contact: Dr. Salah Arafa, Professor of Physics

Activity: Experimental use of small commercial wind pumpers

2. Egyptian Ministry of Electricity
Cairo
Egypt

Contact: Mr. Kamal Hamed, Chairman
Egyptian Electricity Authority
Dr. Mahmood Hegazi

ETHIOPIA

1. Addis Ababa University
Faculty of Technology,
Department of Mechanical Engineering
Addis Ababa
Ethiopia

Contact: Karl Jensen, Department Head

Activity: Wind energy research in the past, during the development through cooperation program

2. Ethiopian Water Resources Authority
P.O. Box 1008
Addis Ababa
Ethiopia

Contact: Teferi Taye, Research Engineer
Activity: Wind pump prototype development and testing

3. African Training and Research Centre for Women*
P.O. Box 3005
Addis Ababa
Ethiopia

Contact: Rose Dakewah, Appropriate Technology Officer
Activity: Uncertain, but reportedly working in windmill design

4. Intermediate Technology Centre*
P.O. Box 10417
Addis Ababa
Ethiopia

Contact: Tesea Negussie
Activity: Uncertain, but this group reportedly has a prototype windmill

GHANA

1. Technology Consultancy Centre*
University of Science and Technology
Kumasi
Ghana

Contact: J.W. Powell
Activity: Small research effort in wind energy

GUINEA

1. Direction Nationale de la Météorologie
Conakry
Guinea

Contact: Comara Mbady
Activity: Weather data collection

2. Service National de l'Hydraulique
P.O. 642
Conakry
Guinea

Contact: Amadou Diallo

3. Ministere de l'Energie
Conakry
Guinea

Contact: Emile Tompapa

4. Institute National de la Récherche et de la Documentation de la Guinea (INRDG)
B.P. 561
Conakry
Guinea

Contact: Sidiki Kobele Keita
Racine Bah
Activity: Research work on wind energy

KENYA

1. Christian Industrial Training Centre (CITC)
P.O. Box 72935
Nairobi
Kenya

Contact: D. Wanjohi
Activity: CITC produced Cretan-type water pumping windmills, but this was stopped in 1978

2. National Christian Council of Kenya (NCCK)
Box 45009
Nairobi
Kenya

Contact: H. Miller
Activity: Ran a windpump project with CITC

3. Village Technology Unit
UNICEF
P.O. Box 44145
Nairobi
Kenya

Contact:
Activity: UNICEF operates a village technology training program at Karen. Objectives are to train extension agents in appropriate technologies, wind pumps included

4. University of Nairobi
Mechanical Engineering Department
P.O. Box 30197
Nairobi
Kenya

Contact: M. Opondo
Activity: The Mechanical Engineering Department has built some experimental windmills and done wind data analysis. Currently, M. Opondo is the leader of wind energy technical panel of university and private people interested in wind energy.

5. <u>University of Nairobi</u>
Department of Meteorology
P.O. Box 30197
Nairobi
Kenya

Contact: Dr. J.K. Mg'ang'a
Activity: Collection of wind data

6. <u>South Turkana Agricultural Development Project</u>, Lakori
P.O. Box 21028
Nairobi
Kenya

Contact:
Activity: Use of CITC Cretan Sail Wind Pump

7. <u>Bobs Harries Engineering, Ltd.</u>
Karamaini Estates
P.O. Box 40
Thika
Kenya

Contact: Mike Harries
Activity: Production of wind pumps

8. <u>Mbita Catholic Mission</u>
Mbita
South Nyanza
Kenya

Contact: Herman M. Carlsen
Activity: Production of wind pumps

9. <u>Plough and Allied Products</u>
Kisumu
Kenya

Contact:
Activity: Production of wind pumps

LESOTHO

1. <u>Ministry of Rural Development</u>
P.O. Box 686
Maseru 100
Lesotho

Contact: M.T. Hlabana
Activity: Installation of commercial water pumping windmills for village water supply.

2. <u>Hydrological and Meteorological Services Branch</u>
Ministry of Water Energy and Mining
Maseru 100
Lesotho

Contact:
Activity: Collection of wind data

3. <u>Thaba Tseka Rural Development Programme</u>
P.O. Box 1027
Lesotho

Contact: Frank Weyer, Section Head, Village Technology Unit
Activity: Evaluation of wind energy potential, wind data measurement, and experimental windmill testing

4. <u>Thaba Khupa Ecumenical Farm Institute</u>
P.O. Box 929
Maseru
Lesotho

Contact:
Activity: Savonius rotor testing

MADAGASCAR

1. <u>Establissement d'Enseignement Superieur Polytechnique*</u>
Université de Madagascar
BP 1500
Antananarivo
Madagascar

Contact:
Activity: Research on wind energy for water pumping and electricity

MALAWI

1. <u>Department of Lands, Valuation and Water*</u>
Private Bag 311
Lilongwe
Malawi

Contact: HR Khoviwa, K. Jellema, L. Mnthali
Activity:

2. <u>University of Malawi*</u>
Bunda College
P.O. Box 219
Lilongwe
Malawi

Contact: Mr. L. Mwinjilo
Activity: Research and development of water pumping windmills for irrigation for possible future commercial production

MALI

1. Ecole Nationale d'Ingenieurs de Mali
   Bamako
   Mali

   Contact:
   Activity: Has carried out a survey of wind data and will be continuing wind energy activities under the AID/Solar Energy Lab Project

2. Peace Corps
   B.P. 85
   Bamako
   Mali

   Contact: D. Benafel, H. Homeyer
   Activity: Technical and financial support in installing small scale irrigation windmills

3. Solar Energy Lab
   B.P. 134
   Bamako
   Mali

   Contact: C. Traore, Director; Terry Hart
   Activity: Wind energy assessment and possibly prototype design

4. Catholic Mission
   Segou
   Mali

   Contact: Father Jean Plasteig
   Activity: Builds Sahores windmills and conducts training courses

MAURITANIA

1. Agence pour la Securité de la Navigation Aerienne en Afrique et a Madagascar
   Nouakchott
   Mauritania

   Contact:
   Activity: Collection of wind data

2. USAID
   U.S. Embassy
   Boite Postal 222
   Noukchott
   Mauritania

   Contact:
   Activity: Contracted feasibility study of wind energy to VITA (Volunteers in Technical Assistance)

MAURITIUS

1. University of Mauritius*
   School of Industrial Technology
   Electrical Engineering Division
   Unjore Lane
   Mon Desir
   Vocoas
   Mauritius

   Contact: V. Pudaruth
   Activity: Compilation and analysis of wind data, prototype construction of electric wind machines

NIGER

1. ONERSOL*
   B.P. 621
   Niamey
   Niger

   Contact:
   Activity: Reported to have wind energy activities

SENEGAL

1. Caritas-Senegal
   B.P. 439
   Dakar
   Senegal

   Contact: Frère Piccard; Silvere Ndiaye
   Activity: Installation of two electric windmills to drive electric pumps

2. Centre d'Etudes et de Récherche sur les Energies Renouvables (CERER)
   Universite de Dakar
   B.P. 5085
   Dakar
   Senegal

   Contact: Andre Kergreis, Director
   Activity: Testing of a Savonius water pumper from SINAES

3. Ambassade de l'Italie
   Dakar
   Senegal

   Contact: Ousmane Gassama
   Activity: Peycouk Project.- use of multiblade windmill

4. Institute Universitaire de Technologie (IUT)
Université de Dakar
Dakar
Senegal
Contact:
Activity: Research on Savonius rotors and a giro/ Savonius machine

SEYCHELLES

1. Ministry of Planning and Development*
P.O. Box 53
Republic of Seychelles
Contact: M. Fauon, Principal Secretary
Activity: Research on wind electric generation

SOMALIA

1. National Refugee Commission
Mogadishu
Somalia
Contact: Mr. Abdi Mohammed Tarah - extraordinary commissioner
Mr. Ahmed Yassin Isse - commissioner

2. National University of Somalia
Mogadishu
~~Somalia~~
Contact: Dr. Abdirazah M. Bihi - Dean of the Faculty of Engineering

SOUTH AFRICA

1. South African Weather Bureau
Pretoria
Republic of South Africa
Contact:
Activity: Wind data collection

2. Climax Windmills (Pty) Ltd.
General Hertzog Road
Box 20244
Peacehaven, 1934, Transvaal
Republic of South Africa
Contact:
Activity: Manufacturer of windmills, towers, and pumps

3. <u>Southern Cross Machinery (Pty) Ltd.</u>
Industrial Area
Bloemfonein
Republic of South Africa
Contact:
Activity: Manufacturer of windmills, towers and pumps

4. <u>Invertex (Pty) Ltd.</u>
P.O. Box 3700
Capetown 3000
Republic of South Africa
Contact: L.P. Cuenoud
Activity: Pilot production of wind generator and inverters

5. <u>Environment and Development Association</u>
Marshalltown
Republic of South Africa
Contact: Robert Berold
Activity: Construction of an experimental Savonius rotor, publication of an Appropriate Technology newsletter, <u>Link</u>

6. <u>Semiconductor Services</u>
Sandberg Street
Denver 2091
Johannesburg
Republic of South Africa
Contact:
Activity: Distribution of Winco wind generator, development of a new wind generator

7. <u>Vetsak*</u>
P.O. Box 380
Isando 1600
Republic of South Africa
Contact: Manager
Activity: Manufacturer of windmill pumping units

SUDAN

1. <u>Department of Mechanical Engineering, University of Khartoum</u>
Khartoum
Sudan
Contact: Dr. Jahia Hassan Hamid
Activity: Have investigated wind power in the past

2. <u>National Council of Research</u>
Khartoum
Sudan
Contact: Dr. Samani Yakoub
Activity: Had planned windmill experimentation program in 1975

3. Mechanical Engineering Department
Well Boring and Water Installation Division
Sudan Gezira Board
Hassaheisha
Sudan

Contact:
Activity: Have installed windpumps

TANZANIA

1. Arusha Appropriate Technolc.jy Project
P.O. Box 764
Arusha
Tanzania

Contact: Steve Kitutu; M. Khatibu
Activity: Development of Arusha wind pump, development of a wind generator, windmill attachment for well drilling and grain grinding

2. Ujuzi Leo Industries
P.O. Box 764
Arusha
Tanzania

Contact:
Activity: Production of Arusha wind pump

3. University of Dar Es Salaam
Department of Agricultural Engineering and Land Planning
P.O. Box 643
Morogoro
Tanzania

Contact: F.M. Inns; Alex Wier
Activity: Assessment of wind power in Tanzania, development of meteorological devices, development of water pumping and grain grinding windmills

4. University of Dar Es Salaam
Department of Mechanical Engineering
P.O. Box 35131
Dar Es Salaam
Tanzania

Contact: Dr. Silas Lwakabamba; Edwin T.P. Protzen
Activity: Design, construction, and testing of wind pumps

5. University of Dar Es Salaam
Department of Electrical Engineering
P.O. Box 35131
Dar Es Salaam
Tanzania

Contact:
Activity: Development of wind data measuring and recording devices, feasibility studies on rural electrification by wind power

6. UTAFITI - (Tanzanian National Science Research Council)
P.O. Box 4302
Dar Es Salaam
Tanzania

Contact:
Activity: Installation of commercial wind pumps, prototype construction and testing

7. The Diocese of Musoma
P.O. Box 93
Musoma
Tanzania

Contact: Rev. J. Conard; Rev. D. Jones
Activity: Pilot wind project in Mara Region

TUNISIA

1. Centre de Récherches de Genie Rural
Boite Postale 10
Ariana
Tunisia

Contact: Mr. El Amami Slaheddine, Director
Activity: Research and development on water pumping windmills

2. Association pour le Développement et l'Animation Rurale (ASDEAR)
10, rue Eve Nohelle
Tunis
Tunisia

Contact: Abdelhafidh Chabbi
Activity: Wind power feasibility, prototype development and production

UPPER VOLTA

1. Comité Interafricain d'Etudes Hydrauliques*
Interafrican Committee for Hydraulic Studies
Boite Postale 369
Ouagadougou
Upper Volta

Contact:
Activity: Research on wind data and wind energy feasibility

ZAMBIA

1. Technology Development and Advisory Unit
   School of Engineering, University of Zambia
   P.O. Box 2379
   Lusaka, Zambia

   Contact: J.P. van Passen
   Activity: Coordination of Zambia wind energy activities, evaluation of wind energy potential, planning local manufacture of windmills

2. Northern Technical College
   Chela Road
   P.O. Box 1563
   Ndola
   Zambia

   Contact: Course Supervisor
   Activity: Training on windmill use

3. Government of Zambia*
   (a) Department of Water Affairs
   (b) Zambian Meteorological Department
   Lusaka
   Zambia

   Contact:
   Activity:

4. Family Farms, Ltd.*
   P.O. Box 42
   Magoye
   Zambia

   Contact:
   Activity: Reportedly manufacturing multiblade windmills and pumps on a limited basis

ZIMBABWE

1. Instutute of Agricultural Engineers
   P.O. Box BW 330
   Borrowdale
   Salisbury
   Zimbabwe

   Contact: Stuart Spence
   Activity: Prototype development

2. <u>Government of Zimbabwe</u>
   (a) Department of Energy Resources
       Ministry of Mines and Energy Resources
       Box 8434
       Causeway
       Salisbury
       Contact: Dr. Mufaro Hove
       Activity; Policy definition, small project support
   (b) Ministry of Water Development
   (c) Ministry of Health

3. <u>Bethlehem Missionary Society</u>
   Metal Work Training
   Postal Bag 9001
   Gwelo
   Zimbabwe
   Contact: Walter Schurtenberger
   Activity: Training on use of windmills

4. <u>Silveira House</u>
   P.O. Box 545
   Salisbury
   Zimbabwe
   Contact: Rev. Brian MacGarry
   Activity: Many aspects of appropriate technology

OTHER CONTACTS: DEVELOPED WORLD

CANADA

1. IDRC (International Development Research Centre)
   P.O. Box 8500
   Ottawa
   Canada
   Contact:
   Activity: Applied research on wind energy for use in developing countries

2. University of Waterloo
   Faculty of Engineering
   Waterloo
   Ontario N2L 3GI
   Canada
   Contact: G.M. Bragg
   Activity: Applied research on wind energy for use in developing countries

3. Brace Research Institute
   MacDonald College of McGill University
   1 Stewart Park
   Ste. Anne de Bellevue
   Quebec H9X 1CO
   Canada
   Contact: Tom Lawand
   Activity: Research and development, field testing, publications

NETHERLANDS

1. Steering Committee for Wind Energy in Developing Countries (SWD)
   P.O. Box 85
   3800 AB Amersfoort
   Netherlands
   Contact: W.A.M. Jansen
   Activity: Research and development, feasibility studies, field testing, publications

2. Eindhoven University of Technology
   Wind Energy Group
   Department of Physics, Building W & S
   P.O. Box 513
   5600 MB Eindhoven
   Netherlands

3. Working Group on Development Technology (WOT)
Twente University of Technology
Vrijhof 152
P.O. Box 217
7500 AE Enschede
Netherlands

Contact:
Activity: Prototype development and testing

SWITZERLAND

1. World Council of Churches
Commission on the Churches' Participation in Development
150 Route de Ferney
P.O. Box 66
CH-1211 Geneva 20

Contact: Pascal de Pury
Activity: Information dissemination. This group was involved in disseminating the Sahores mill

UNITED KINGDOM

1. Intermediate Technology Development Group
9 King Street
London WC2 8HN
England

Contact: Information Officer
Activity: Wind pump research and development, technical assistance, publications

2. Commonwealth Secretariat
Marlborough House
Pall Mall
London SW14 5HX

Contact: Antony Ellman
Activity: Support of wind energy efforts in developing countries

UNITED STATES OF AMERICA

1. Peace Corps
906 Connecticut Avenue, N.W.
Washington, D.C. 20525
USA

Contact: Paul Jankura
Activity: Volunteer participation in all aspects of wind energy

2. VITA (Volunteers in Technical Assistance)
1815 North Lynn Street, Suite 200
Arlington, Virginia 22209
USA

Contact: Alan Wyatt
Activity: Information dissemination, networking, publications, small project support for renewable energy in developing countries

3. Agency for International Development
Department of State
Washington, D.C. 20520
USA

Contact: Steve Klein

4. National Climatic Center
Asheville, North Carolina 28801
USA

Contact:
Activity: Maintain extensive weather data files for all parts of the world. Due to occasionally poor collection procedures, its use for wind machine siting and analysis is questionable

5. Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401
USA

Contact: Amir Mikhail, Richard Flood
Activity: Technical support to Mali Solar Energy Lab/AID project

6. U.S. Department of Energy
FORRESTAL 5F-081
Washington, D.C. 20545
USA

Contact: Carl Aspliden
Activity: International wind energy programs

7. Pacific Northwest Laboratories
Battelle Boulevard
Richland, Washington 99352
USA

Contact: D.L. Elliott
Activity: World wide wind resource assessment

BIBLIOGRAPHY

GENERAL

1. Commonwealth Workshop On Low-Cost Energy for Water Pumping. Conclusions and Recommendations. Rural Industries Innovation Center, Kanye, Botswana. November 24-29, 1980.

2. Renewable Energy Resources in the Developing Countries. World Bank, 1818 H Street, N.W., Washington, D.C. 20433 USA. January 1981.

3. "An International Development Program to Produce a Wind-powered Water-Pumping System Suitable for Small-Scale Economic Manufacture," by P.L. Fraenkel, ITDG. Second International Wind Energy Systems Conference. October 3-6, 1978.

4. International Directory of Appropriate Technology Resources, compiled by Brij Mathur, a VITA publication, VITA Inc. 1979.

5. Appropriate Technology Directory by Nicolas Jequier with the assistance of Gerard Blanc from the Development Center of the Organization for Economic Co-operation and Development. Paris 1979.

6. Rural Technology in the Commonwealth, a directory of organizations. Compiled by Bruce Mackay. Commonwealth Secretariat 1980.

7. Wind Energy, a bibliography with abstracts and keywords by Joop Meel, Dirk Hengeveld from the Department of Physics, the Wind Energy Group, Eindhoven University of Technology, Eindhoven, the Netherlands, March 1977, Part 3 and 4.

8. Wind as an Energy Resource for Water Pumping, by R. Carothers.

9. Ground Water in Africa, Department of Economics and Social Affairs, United Nations, New York, 1973.

10. L'Energie Eolienne dans le Sahel. Etude Preliminaire sur les possibilites d'utiliser l'energie eolienne pour le pompage d'eau dans le Sahel. Par L.M. Paulissen et J.C. Doorn. By S.W.D. Amersfoot, Netherlands. Mars 1977.

11. "The Cost Effectiveness of Water Pumping Windmills," P.R. Gingold. The Development Corporation, St. Vincent, West Indies. From Wind Engineering Quarterly, Vol. 3 no. 4, 1979.

BOTSWANA

1. An Assessment of Water Pumping Technologies Using Locally Available Energy Resources - Botswana. R. Carothers, Rural Industries Innovation Center, Pr. Bag 11, Kanye, Botswana, July 1980.

2. "'Mono' Comes of Age," Farm Implement and Machinery Review, August 1, 1956, page 607.

CAPE VERDE

1. L'Energie Eolienne Au Cabo Verde. Une etude preparatoire des besoins et des possibilites de l'utilisation de l'energie eolienne. Par J.C. Van Doorn et L.M.M. Paulissen. By S.M.W. Amersfoot, Netherlands. Premiere Edition Aout 1976, Reimpression Avril 1980.

2. AID Renewable Energy Program; Cape Verde Project Report 655-0009, July 1979

3. Wind Energy Resources in the Cape Verde Islands. Steve Blake, Sunflower Power Company. Route 1, Box 93-A, Oskaloosa, Kansas 66066, USA (913) 842-0298--The wind energy portion of the AID report in 2 above. 1979.

EGYPT

1. Egyptian Wind Energy Resources Study, Final Report Phase II, William L. Hughes, Engineering Energy Laboratory, Oklahoma State University, Stillwater, Oklahoma 74074 USA. A joint program of study on wind energy resources in Egypt conducted by the Egyptian Ministry of Electricity and Oklahoma State University and financed by the National Science Foundation under NSF Grant no. EH-78-c-02-4638.

2. Harnessing Wind Power In Developing Countries, R. Ramakumar, 10th IECEC, Newark, Delaware, August 1975.

3. ITDG Project Bulletin, September 1980.

ETHIOPIA

1. Polomo Windmills - Omo River; A.T. Unit Report No. 4, Appropriate Technology Unit, Christian Relief and Development Association, P.O. Box 5674, Addis Ababa, Ethiopia. October 1975.

2. Food From Windmills by Peter L. Fraenkel, B.Sc. (Eng) Intermediate Publications Ltd., 9 King Street, London WCE 8HN England, November 1975.

3. Low-Cost Energy Sources for Water Pumping in Ethiopia, by Teferi Taye, Ethiopian Water Resources Authority for low cost energy for water pumping workshop, Botswana, 1980.

THE GAMBIA

1. How to Build a Cretan Sail Wind-Pump, by R.D. Mann, Agricultural Officer Gambia Christian Council, West Africa. Intermediate Technology Publications Ltd, 1979.

GUINEA

1. "Appropriate Technology in Guinea, Report and Recommendations", VITA, 1981.

KENYA

1. Water Pumping by Wind Energy in Kenya (as at 1980). Prepared by the Wind Energy Technical Panel, University of Nairobi, and Allied Establishments. October 1980 for low cost energy for water pumping workshop, Botswana 1980.

2. South Turkana Agricultural Development Project. Lokori, P.O. Box 21018, Nairobi, Kenya. By the Africa Inland Church.

3. Some Wind Power Developments in Kenya, by D.J. Hilton, International Symposium on Wind Energy Systems. Cambridge, September 7-9, 1976.

LESOTHO

1. Wind Power for Thaba Tseka, Lesotho, an updated report by Alan Wyatt, Thaba Tseka Integrated Rural Development Program. P.O. Box 1027, Maseru, Lesotho, 1980.

2. Water, Health and Development, an interdisciplinary evaluation, by Richard Feachern, Elisabeth Burns, Donald Curtis, Sandy Cairncross, M. Khalid Kha, Aron Croning, Douglas Lamb, Piers Cross, Hilary Southall. Tri-Med Books, Ltd., London. 1978.

MALI

1. Renewable Energy Project, Mali 688-0217, AID Washington, D.C., August 1978.

2. A Technical Study of a Windmill Pump, World Council of Churches, October 1975.

3. Wind and Solar Energy Prototype Development at the Laboratoire D'Energie Solaire, Bamako, Mali, June-September 1981. Alan Wyatt, December 1981, VITA.

MAURITANIA

1. Alternative Energy Systems in Rural Mauritania, by Daniel C. Dunham. A report prepared for AID and published by VITA. September 1977.

2. Report to VITA on Wind Energy in Mauritania, submitted by William L. Hughes, Director Engineering Energy Laboratory, Oklahoma State University, April 1980.

SENEGAL

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